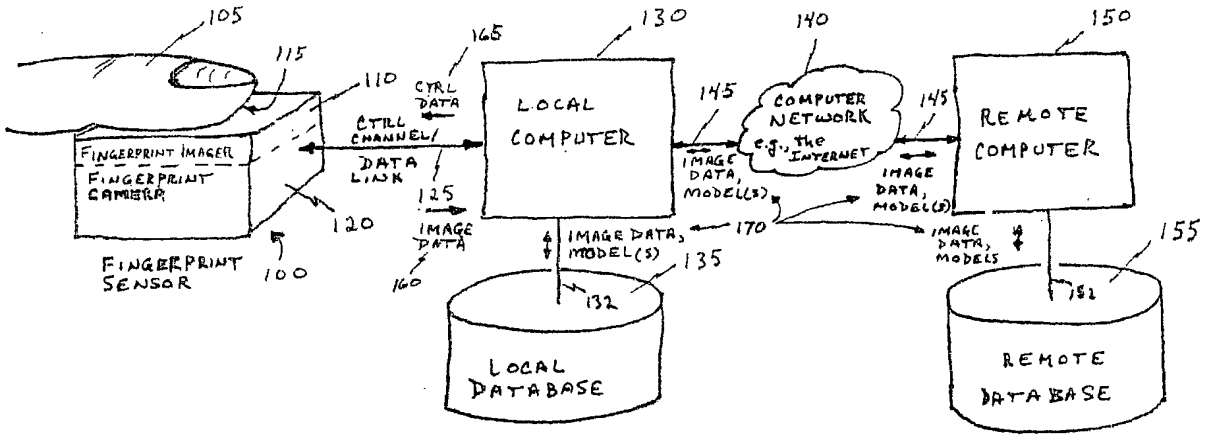
105
115
110
165
130
140
150
CTRL DATA
LOCAL COMPUTER
145
COMPUTER NETWORK
e.g., the INTERNET
145
REMOTE COMPUTER
FINGERPRINT IMAGER
FINGERPRINT CAMERA
CTRL CHANNEL/ DATA LINK
IMAGE DATA, MODEL(S)
IMAGE DATA, MODEL(S)
125
120
IMAGE DATA
IMAGE DATA, MODEL(S)
170
IMAGE DATA, MODELS
155
FINGERPRINT SENSOR
100
160
135
132
152
LOCAL DATABASE
REMOTE DATABASE

FIG. 1

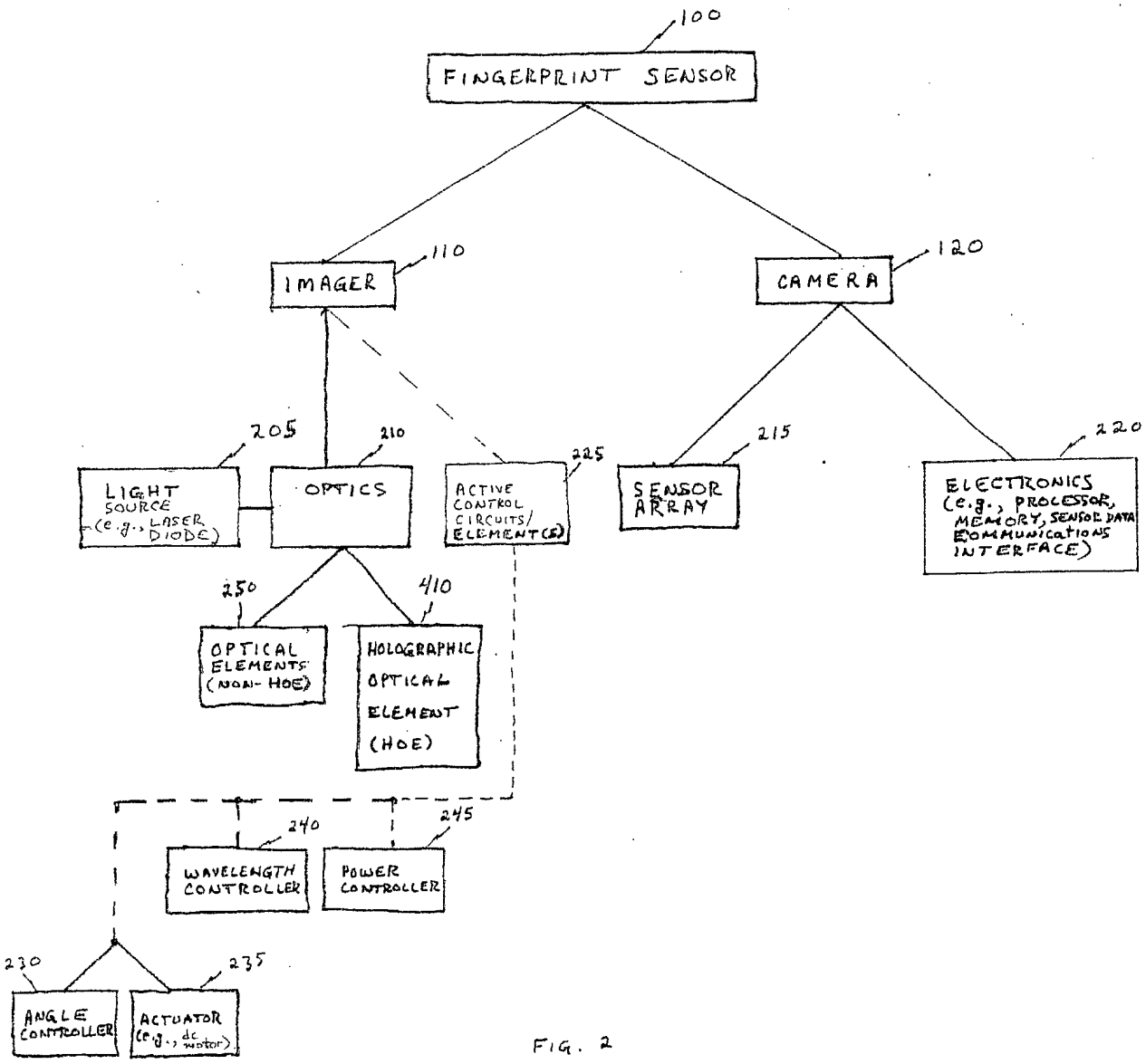
100
FINGERPRINT SENSOR
IMAGER
110
CAMERA
120
205
LIGHT SOURCE (e.g., LASER DIODE)
210
OPTICS
225
ACTIVE CONTROL CIRCUITS/ ELEMENT(S)
215
SENSOR ARRAY
220
ELECTRONICS (e.g., PROCESSOR, MEMORY, SENSOR DATA COMMUNICATIONS INTERFACE)
250
OPTICAL ELEMENTS (NON-HOE)
410
HOLOGRAPHIC OPTICAL ELEMENT (HOE)
240
WAVELENGTH CONTROLLER
245
POWER CONTROLLER
230
ANGLE CONTROLLER
235
ACTUATOR (e.g., dc motor)

FIG. 2

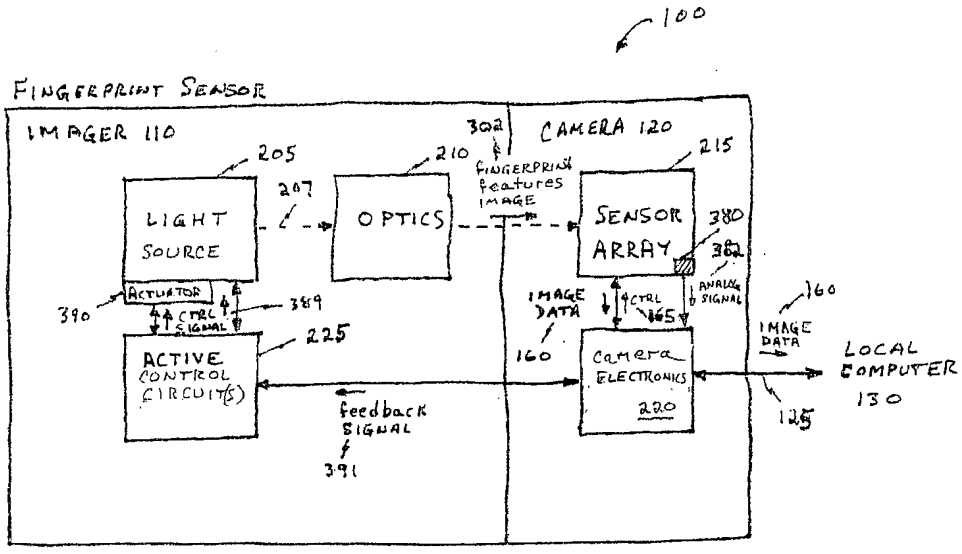
100
FINGERPRINT SENSOR
IMAGER 110
CAMERA 120
205
210
302
215
LIGHT SOURCE
207
OPTICS
FINGERPRINT features IMAGE
SENSOR ARRAY
380
382
ACTUATOR
390
CTRL SIGNAL
389
ANALOG SIGNAL
IMAGE DATA
CTRL 165
160
ACTIVE CONTROL CIRCUIT(S)
225
CAMERA ELECTRONICS 220
IMAGE DATA
LOCAL COMPUTER 130
feedback SIGNAL
391
125

FIG. 3A

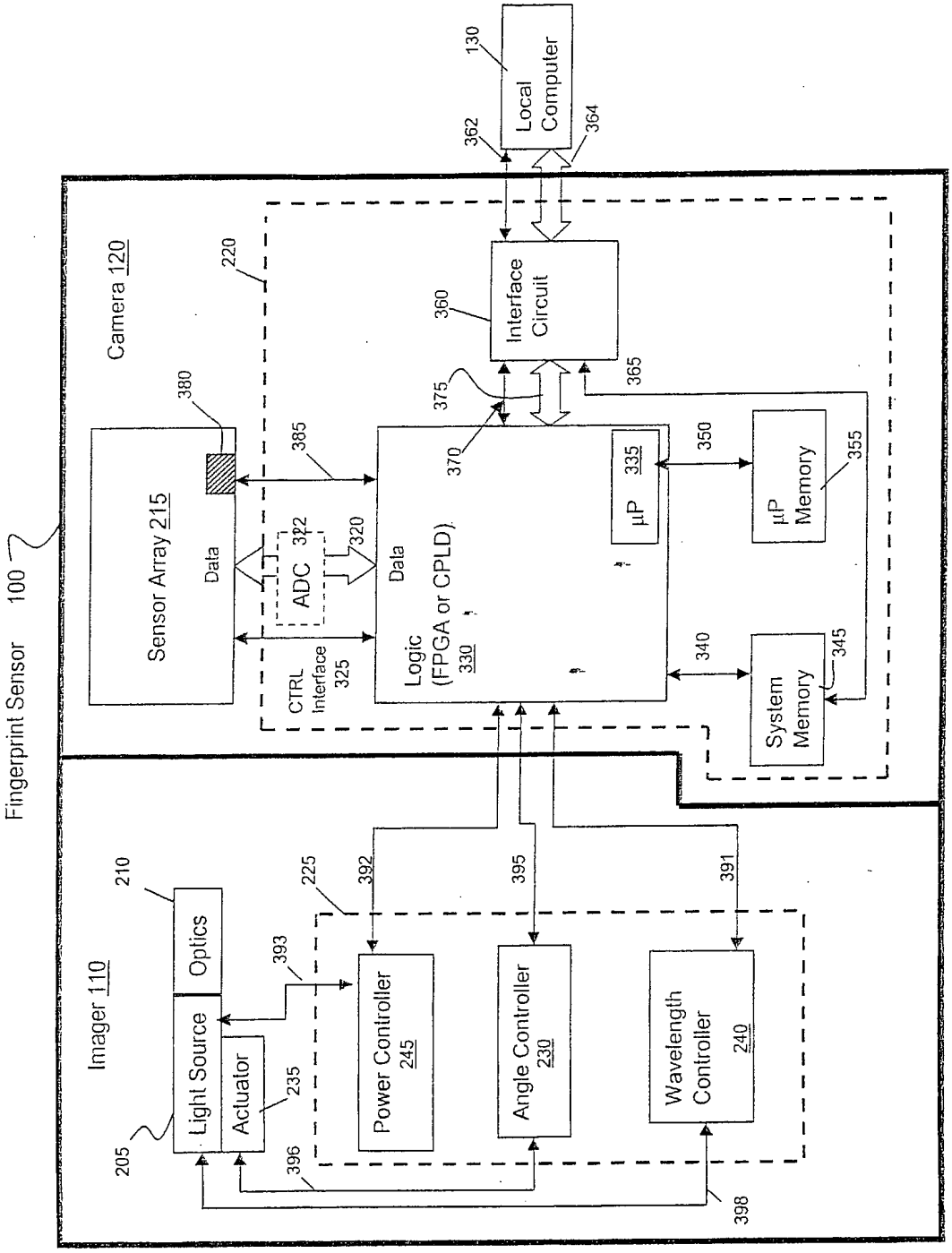
Fingerprint Sensor 100
Camera 120
220
Sensor Array 215
380
Data
385
ADC 322
320
CTRL Interface 325
Data
Logic (FPGA or CPLD) 330
370
375
Interface Circuit 360
365
μP 335
350
μP Memory 355
340
System Memory 345
362
364
Local Computer 130
Imager 110
210
Optics
Light Source 205
Actuator 235
393
225
392
395
391
Power Controller 245
Angle Controller 230
Wavelength Controller 240
396
398

Figure 3B

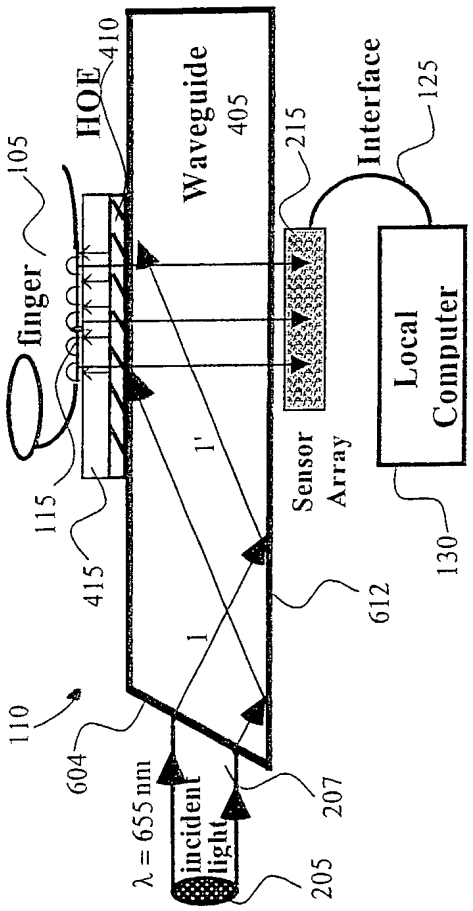
105
finger
HOE
410
Waveguide
405
215
Interface
125
115
415
1'
Sensor
Array
Local
Computer
130
612
1
110
604
λ = 655 nm
incident
light
205
207

FIG. 4

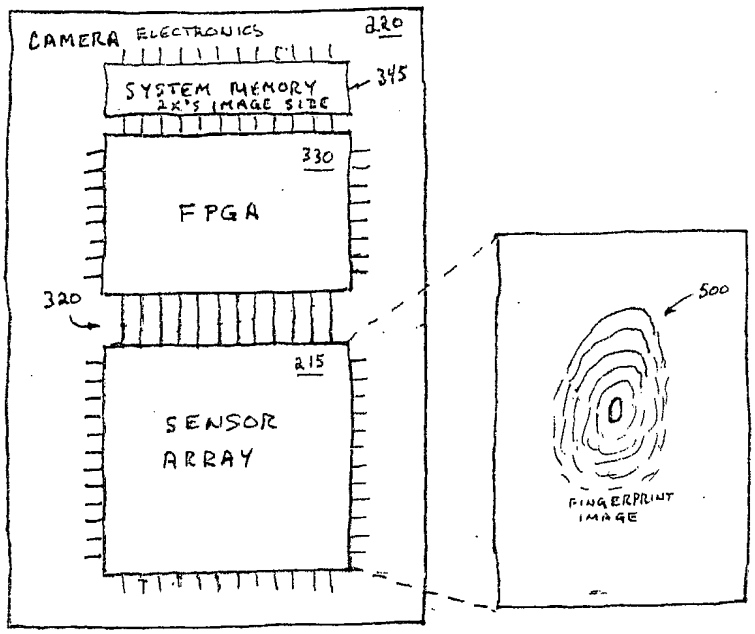
CAMERA ELECTRONICS
220
SYSTEM MEMORY
2K'S IMAGE SIZE
345
330
FPGA
320
215
SENSOR
ARRAY
500
FINGERPRINT
IMAGE

FIG. 5

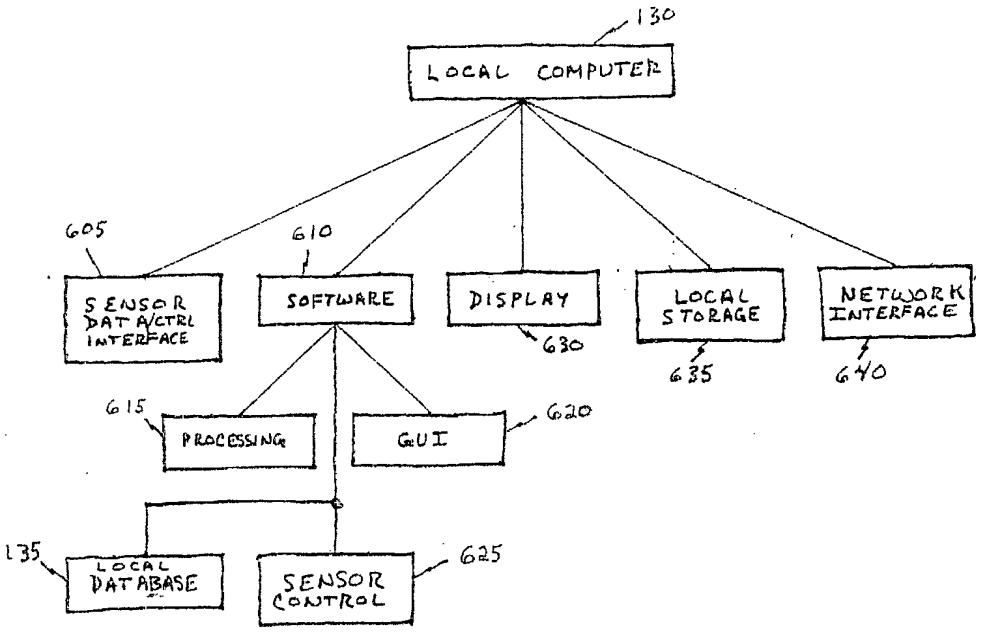
130
LOCAL COMPUTER
605
610
SENSOR DAT A/CTRL INTERFACE
SOFTWARE
DISPLAY
630
LOCAL STORAGE
635
NETWORK INTERFACE
640
615
PROCESSING
GUI
620
135
LOCAL DATABASE
SENSOR CONTROL
625

FIG. 6A

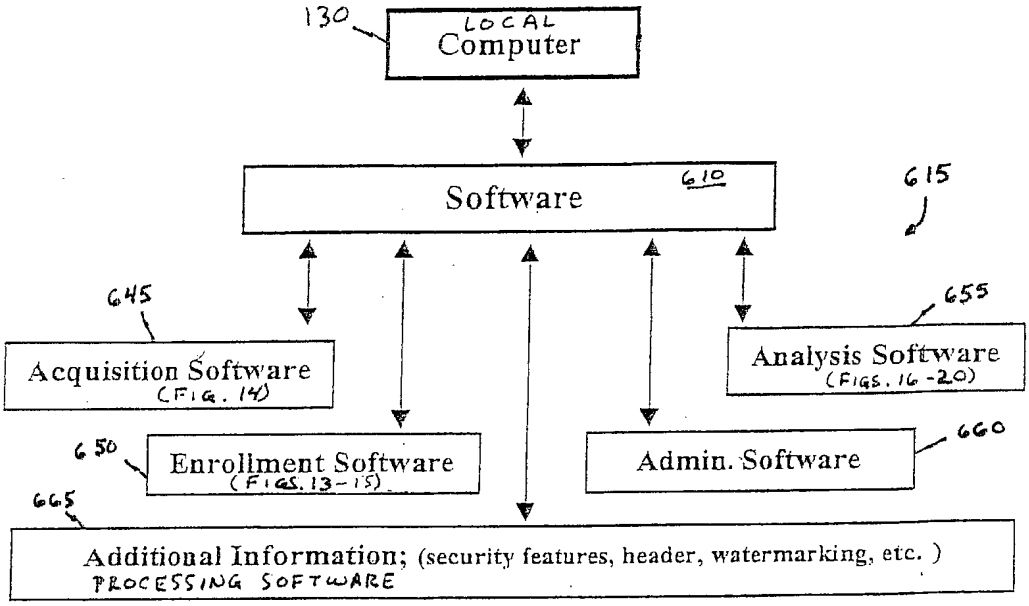
130
LOCAL
Computer
Software
610
615
645
Acquisition Software
(FIG. 14)
655
Analysis Software
(FIGS. 16-20)
650
Enrollment Software
(FIGS. 13-15)
660
Admin. Software
665
Additional Information; (security features, header, watermarking, etc.)
PROCESSING SOFTWARE

FIG. 6B

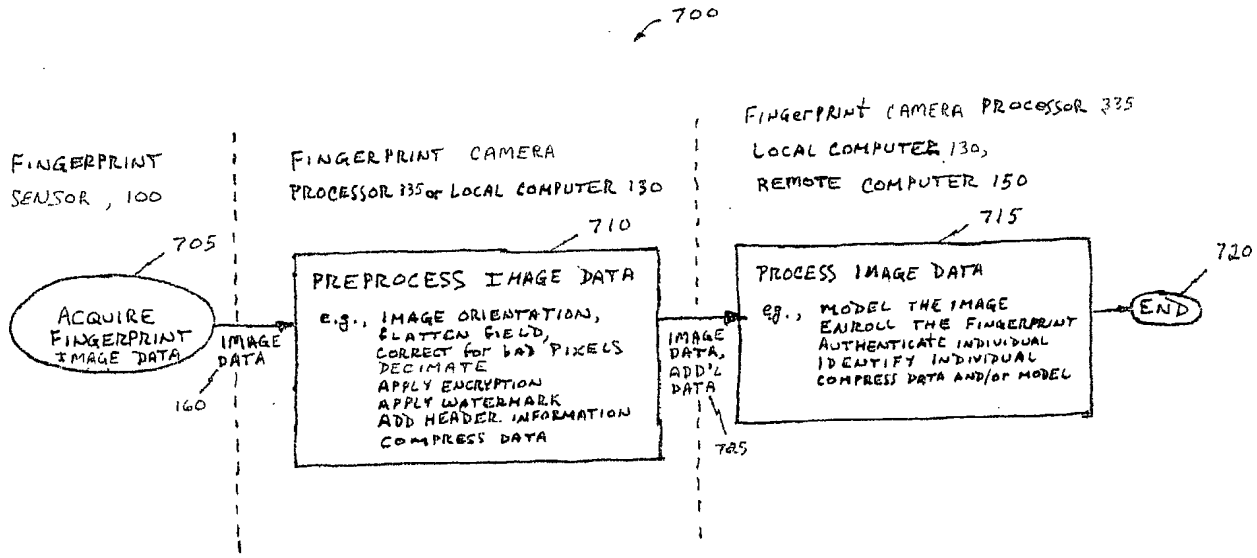
700
FINGERPRINT SENSOR, 100
FINGERPRINT CAMERA PROCESSOR 335 OR LOCAL COMPUTER 130
FINGERPRINT CAMERA PROCESSOR 335
LOCAL COMPUTER 130,
REMOTE COMPUTER 150
705
ACQUIRE FINGERPRINT IMAGE DATA
IMAGE DATA
160
710
PREPROCESS IMAGE DATA
e.g., IMAGE ORIENTATION,
FLATTEN FIELD,
CORRECT FOR BAD PIXELS
DECIMATE
APPLY ENCRYPTION
APPLY WATERMARK
ADD HEADER INFORMATION
COMPRESS DATA
IMAGE DATA, ADD'L DATA
725
715
PROCESS IMAGE DATA
eg., MODEL THE IMAGE
ENROLL THE FINGERPRINT
AUTHENTICATE INDIVIDUAL
IDENTIFY INDIVIDUAL
COMPRESS DATA AND/OR MODEL
720
END

FIG. 7

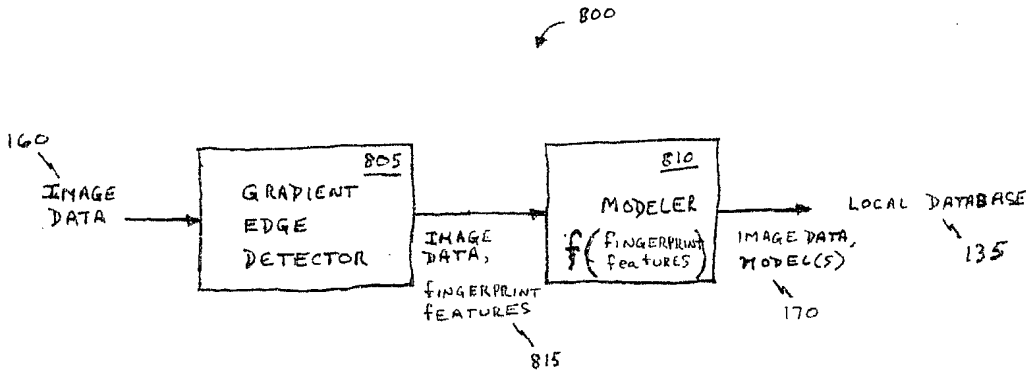
800
160
IMAGE DATA
805
GRADIENT EDGE DETECTOR
IMAGE DATA, FINGERPRINT FEATURES
815
810
MODELER
f(FINGERPRINT features)
IMAGE DATA, MODEL(S)
170
LOCAL DATABASE
135

FIG. 8

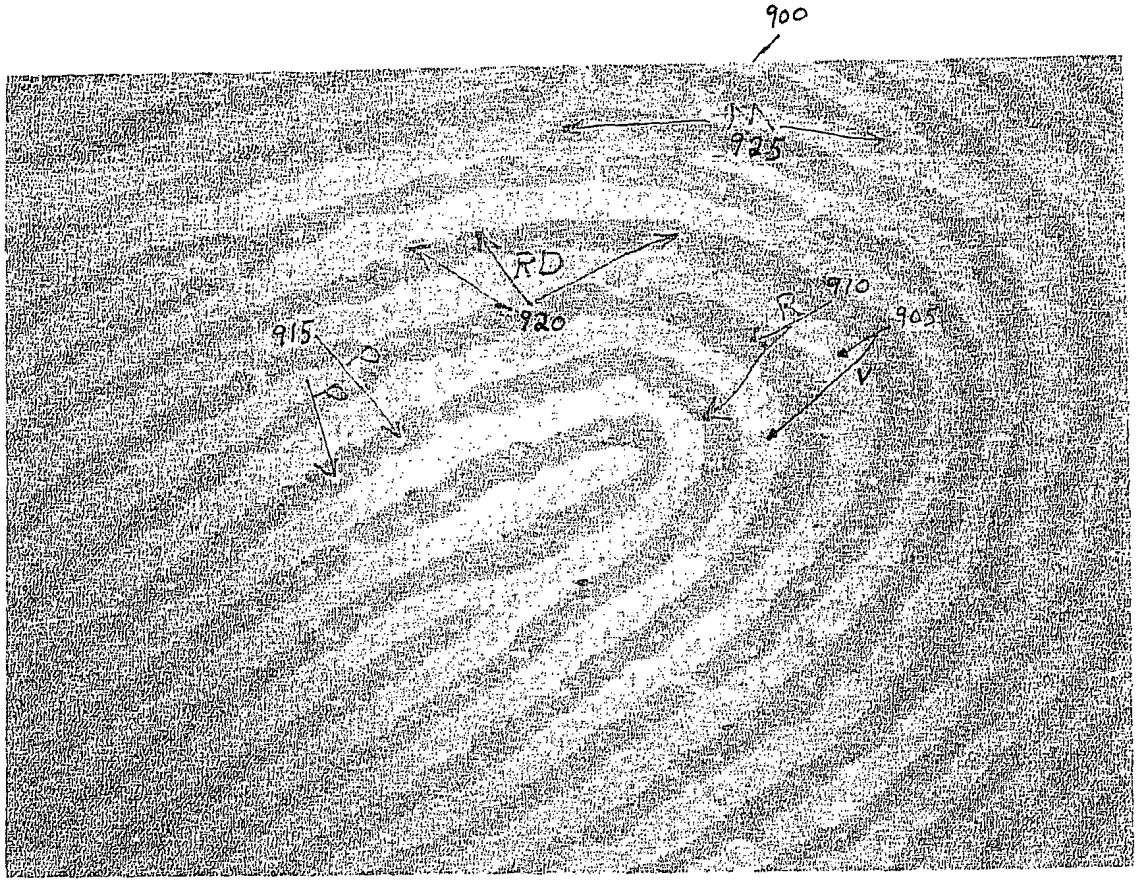

FIG. 9

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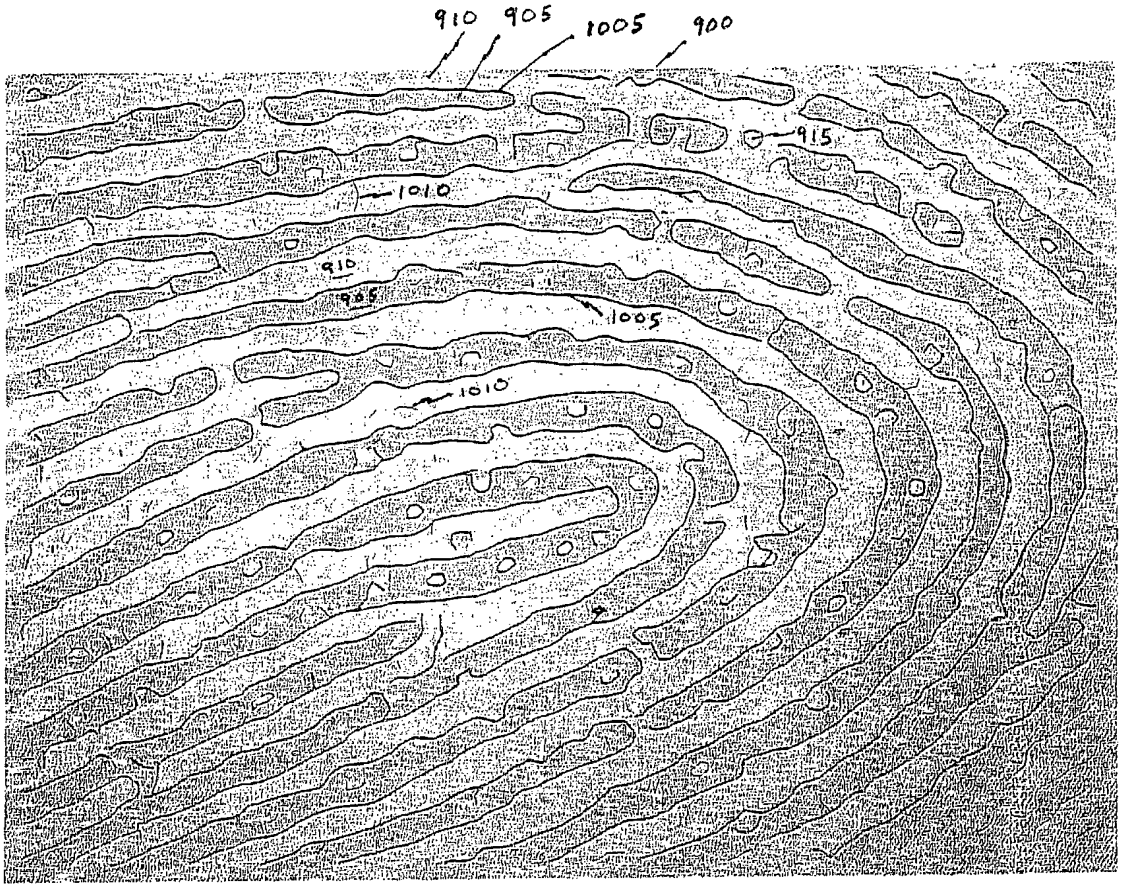

FIG. 10

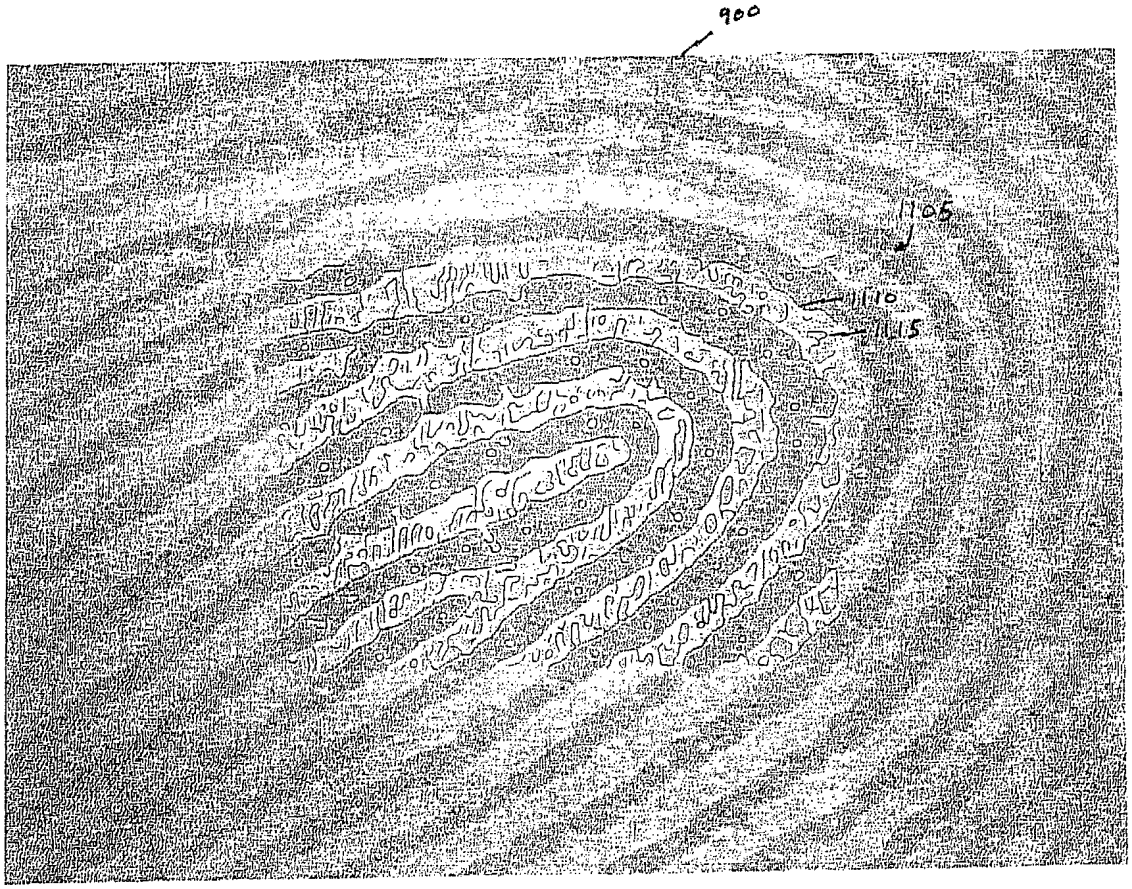

FIG. 11

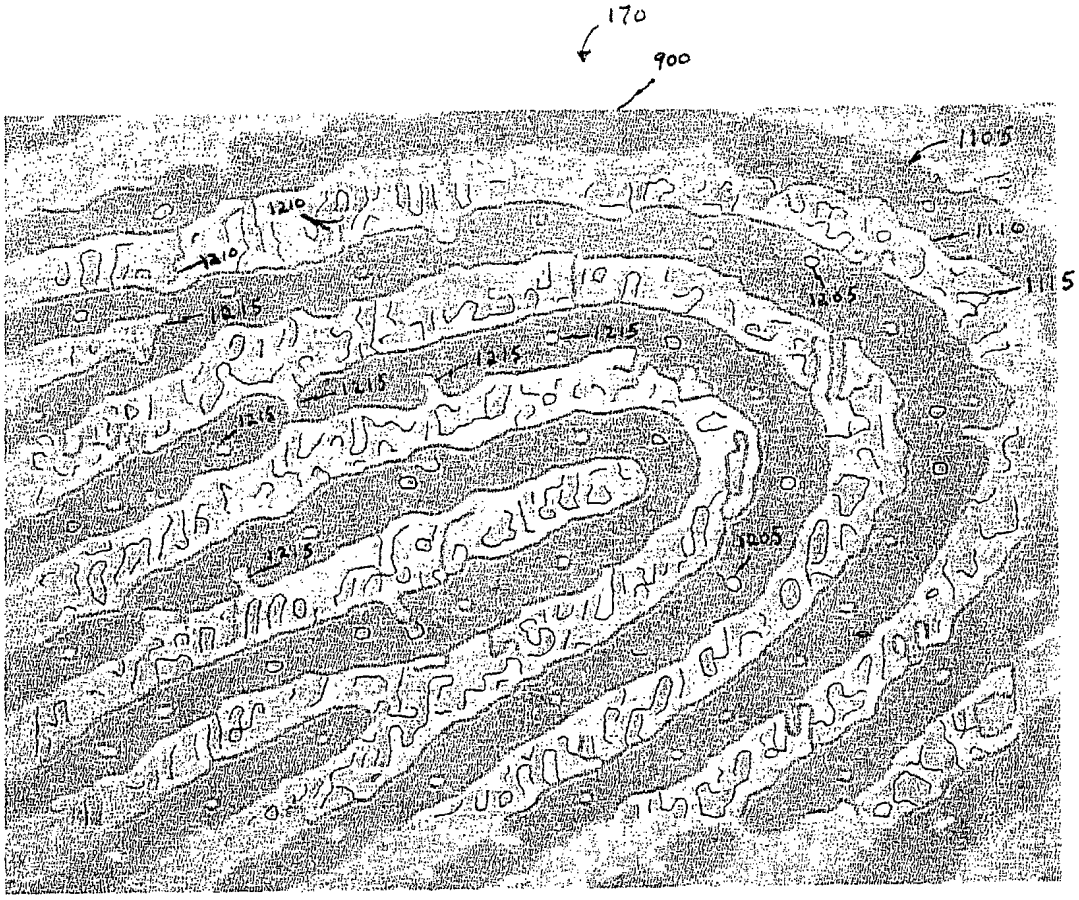

Fig. 12

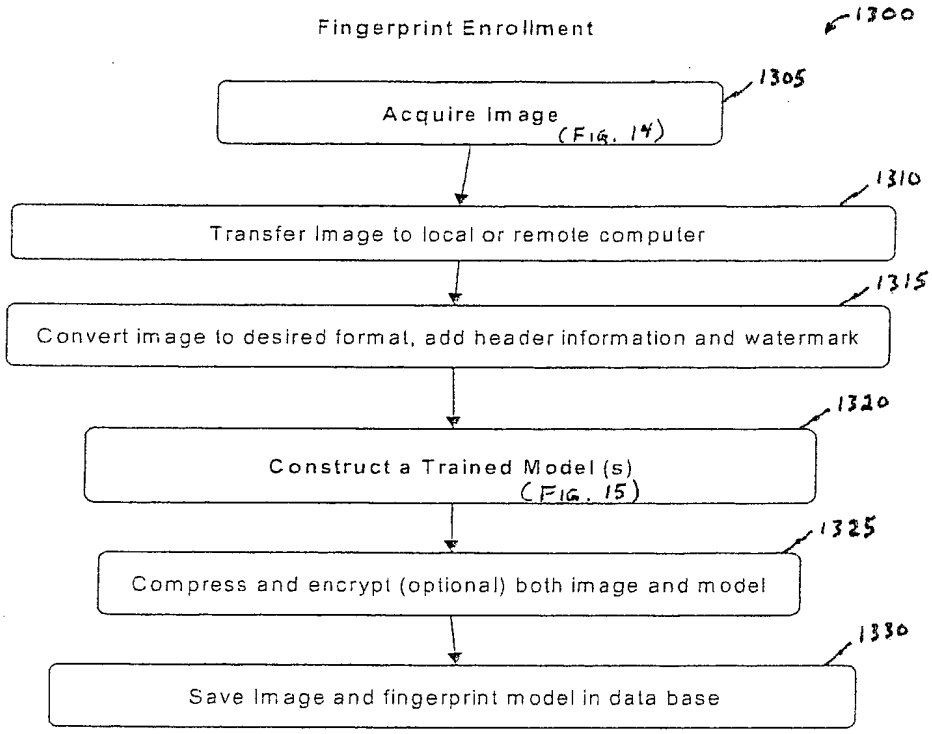
Fingerprint Enrollment
1300
1305
Acquire Image
(Fig. 14)
1310
Transfer Image to local or remote computer
1315
Convert image to desired format, add header information and watermark
1320
Construct a Trained Model (s)
(Fig. 15)
1325
Compress and encrypt (optional) both image and model
1330
Save Image and fingerprint model in data base

Fig. 13

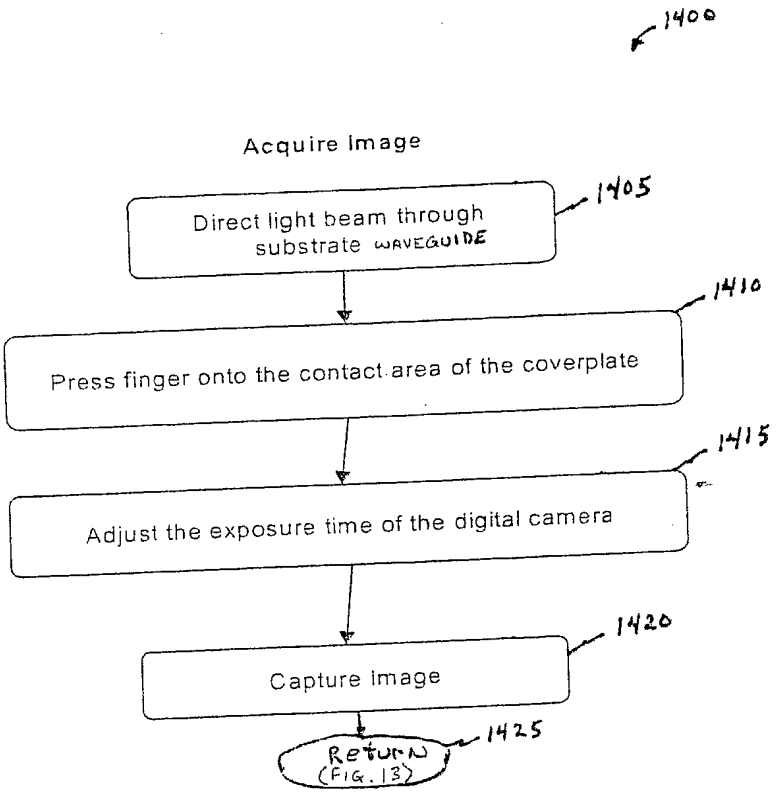
1400
Acquire Image
Direct light beam through substrate WAVEGUIDE
1405
Press finger onto the contact area of the coverplate
1410
Adjust the exposure time of the digital camera
1415
Capture Image
1420
Return (FIG. 13)
1425

FIG. 14

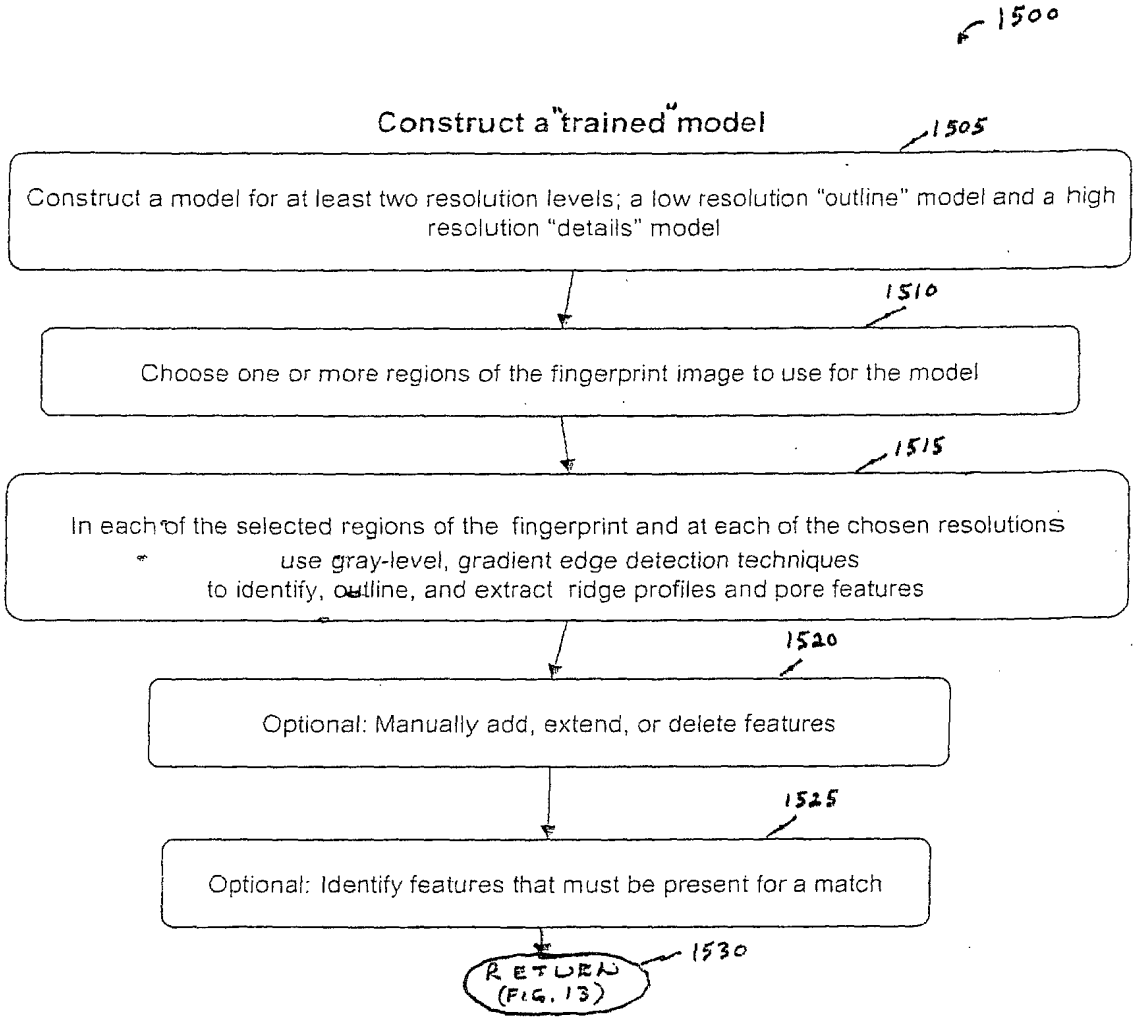
1500
Construct a "trained" model
1505
Construct a model for at least two resolution levels; a low resolution "outline" model and a high resolution "details" model
1510
Choose one or more regions of the fingerprint image to use for the model
1515
In each of the selected regions of the fingerprint and at each of the chosen resolutions use gray-level, gradient edge detection techniques to identify, outline, and extract ridge profiles and pore features
1520
Optional: Manually add, extend, or delete features
1525
Optional: Identify features that must be present for a match
1530
RETURN (FIG. 13)

FIG. 15

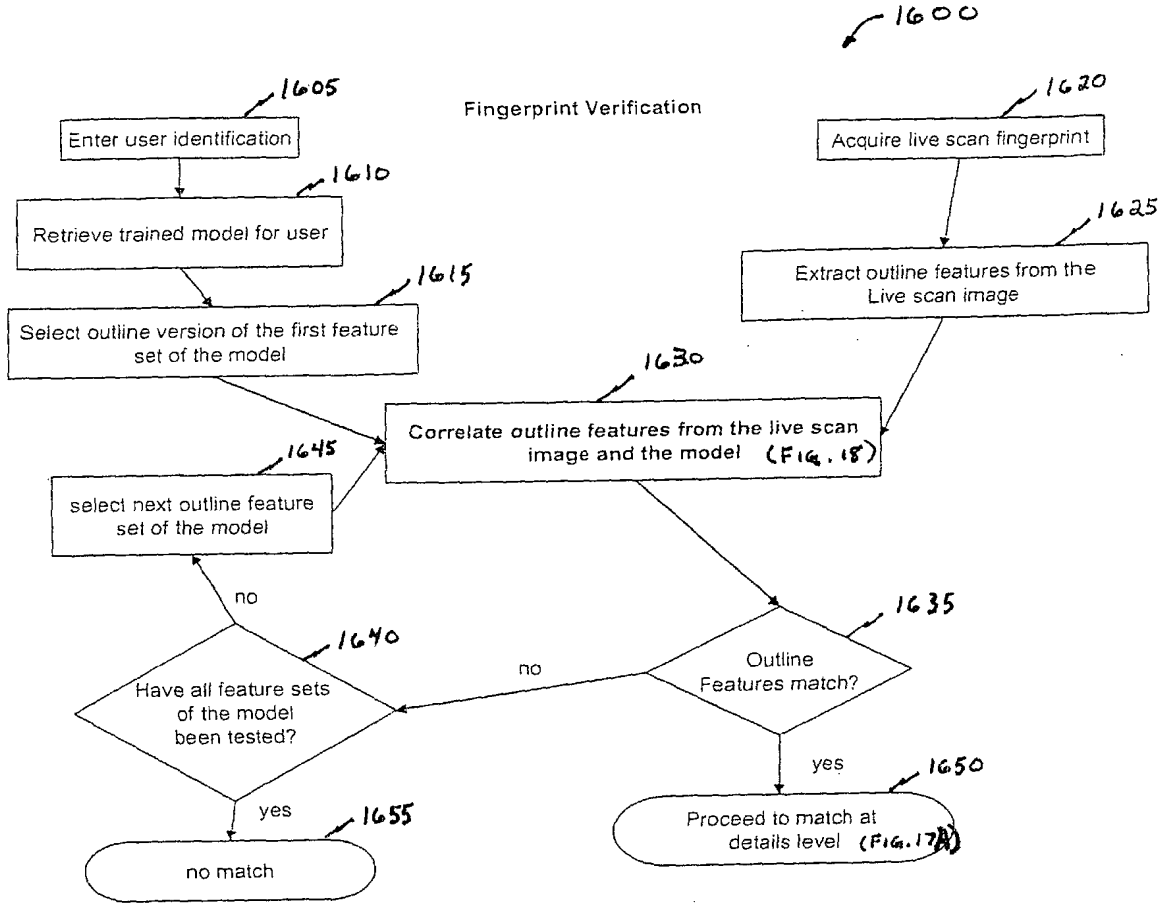
1600
Fingerprint Verification
1605
Enter user identification
1610
Retrieve trained model for user
1615
Select outline version of the first feature set of the model
1620
Acquire live scan fingerprint
1625
Extract outline features from the Live scan image
1630
Correlate outline features from the live scan image and the model (FIG. 18)
1635
Outline Features match?
1640
Have all feature sets of the model been tested?
1645
select next outline feature set of the model
1650
Proceed to match at details level (FIG. 17A)
1655
no match
no
yes
no
yes

FIG. 16

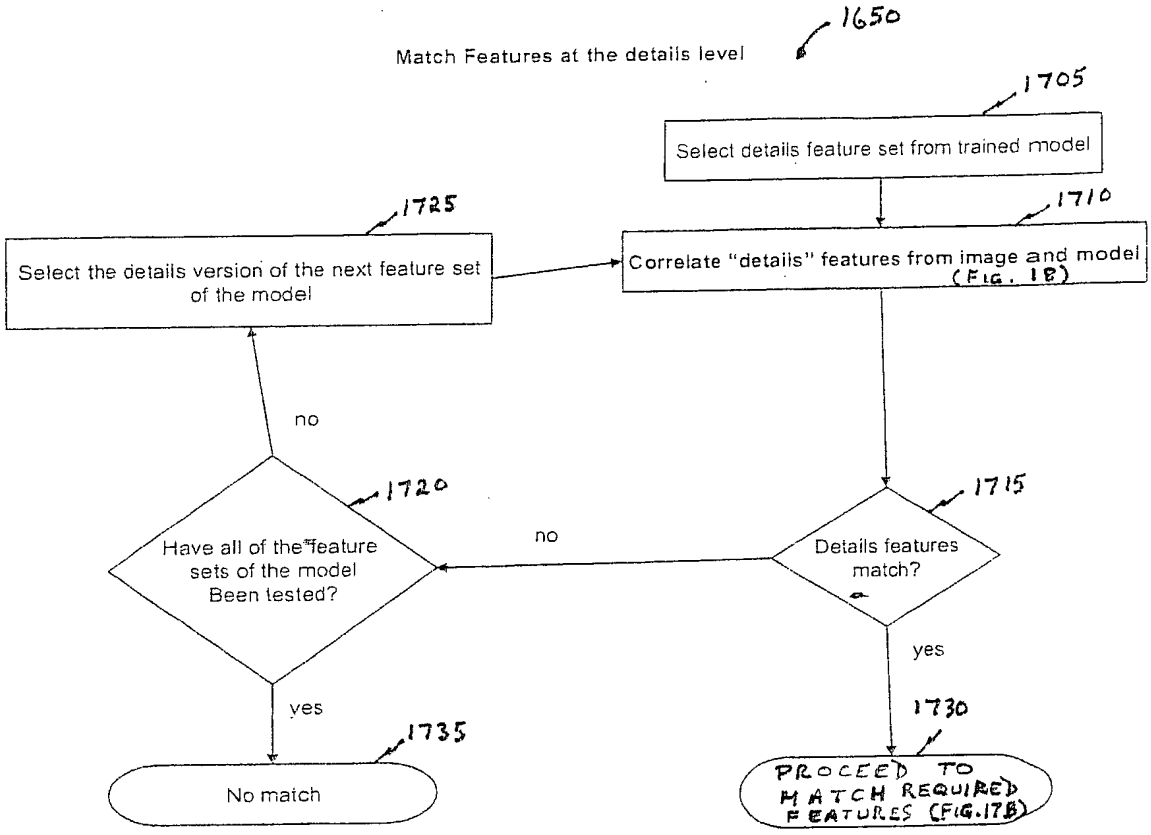
Match Features at the details level
1650
1705
Select details feature set from trained model
1710
Correlate "details" features from image and model (FIG. 18)
1715
Details features match?
no
yes
1720
Have all of the feature sets of the model Been tested?
no
yes
1725
Select the details version of the next feature set of the model
1730
PROCEED TO MATCH REQUIRED FEATURES (FIG. 17B)
1735
No match

FIG. 17A

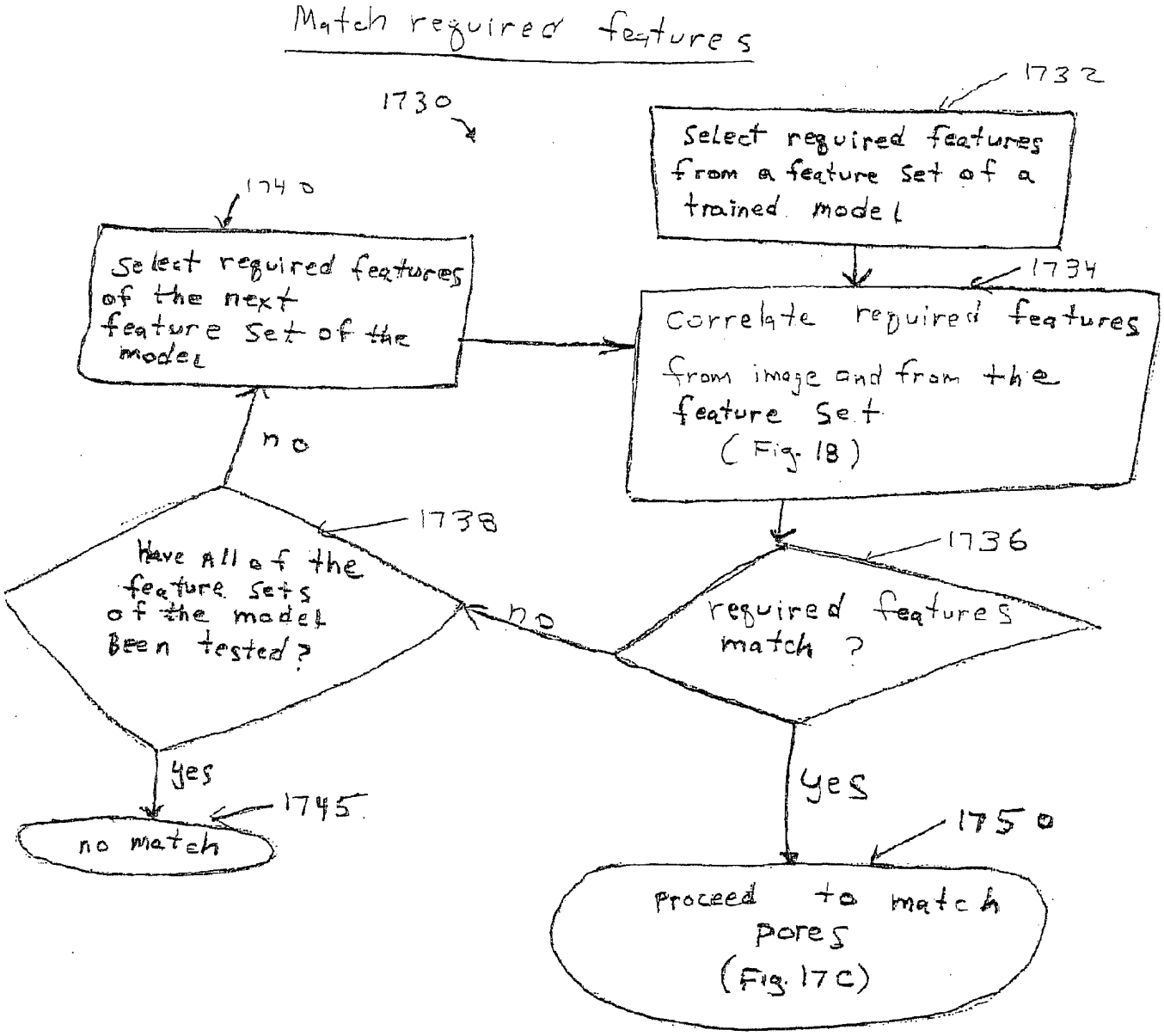
Match required features
1730
1732
Select required features from a feature set of a trained model
1740
Select required features of the next feature set of the model
1734
Correlate required features from image and from the feature set (Fig. 18)
no
1738
Have All of the feature sets of the model been tested?
1736
required features match ?
no
yes
1745
no match
yes
1750
Proceed to match pores (Fig. 17C)

Fig. 17B

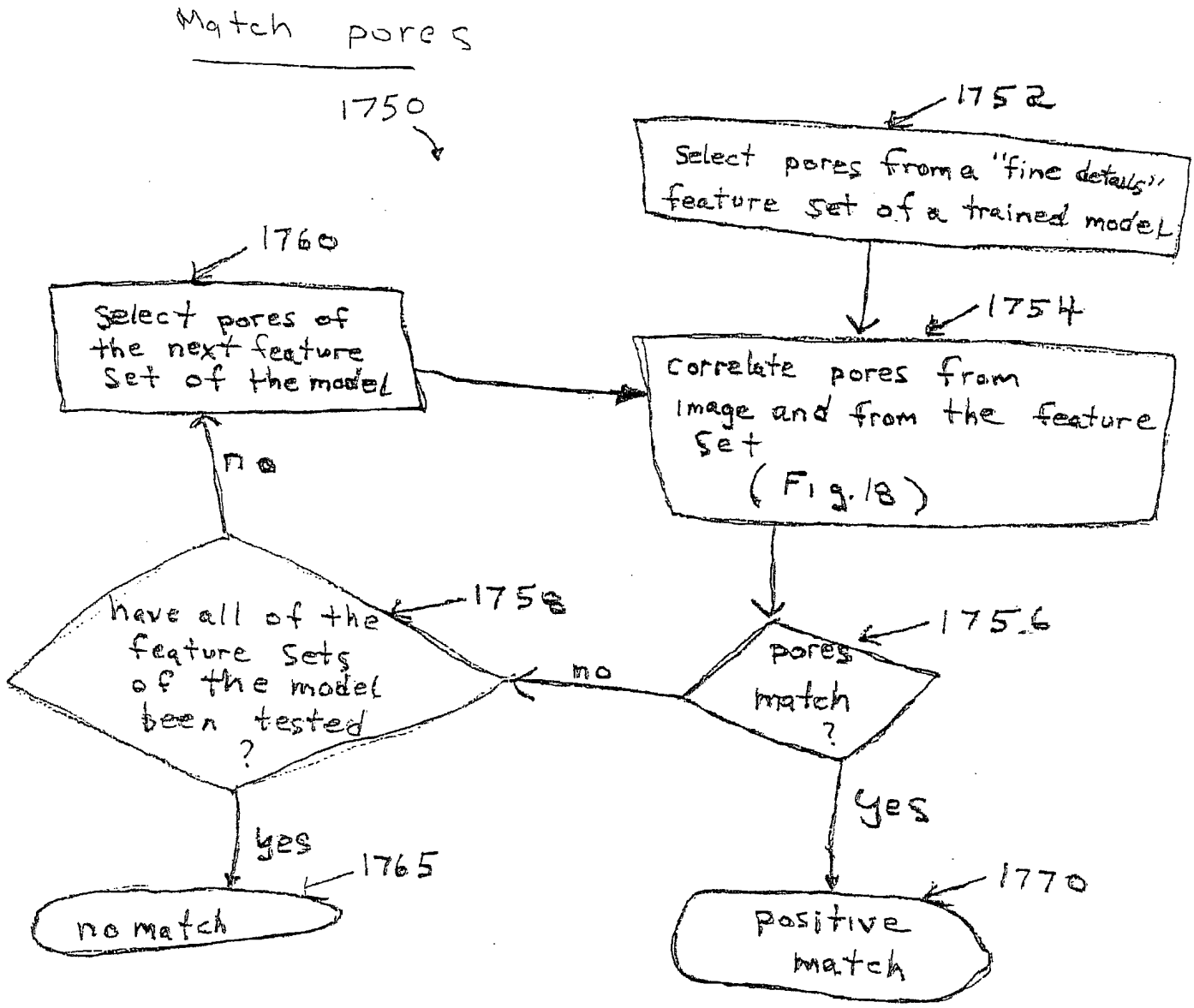
Match pores
1750
1752
Select pores from a "fine details" feature set of a trained model
1754
Correlate pores from image and from the feature set (Fig. 18)
1756
pores match ?
yes
1770
positive match
no
1758
have all of the feature sets of the model been tested ?
yes
1765
no match
no
1760
Select pores of the next feature set of the model

Fig. 17C

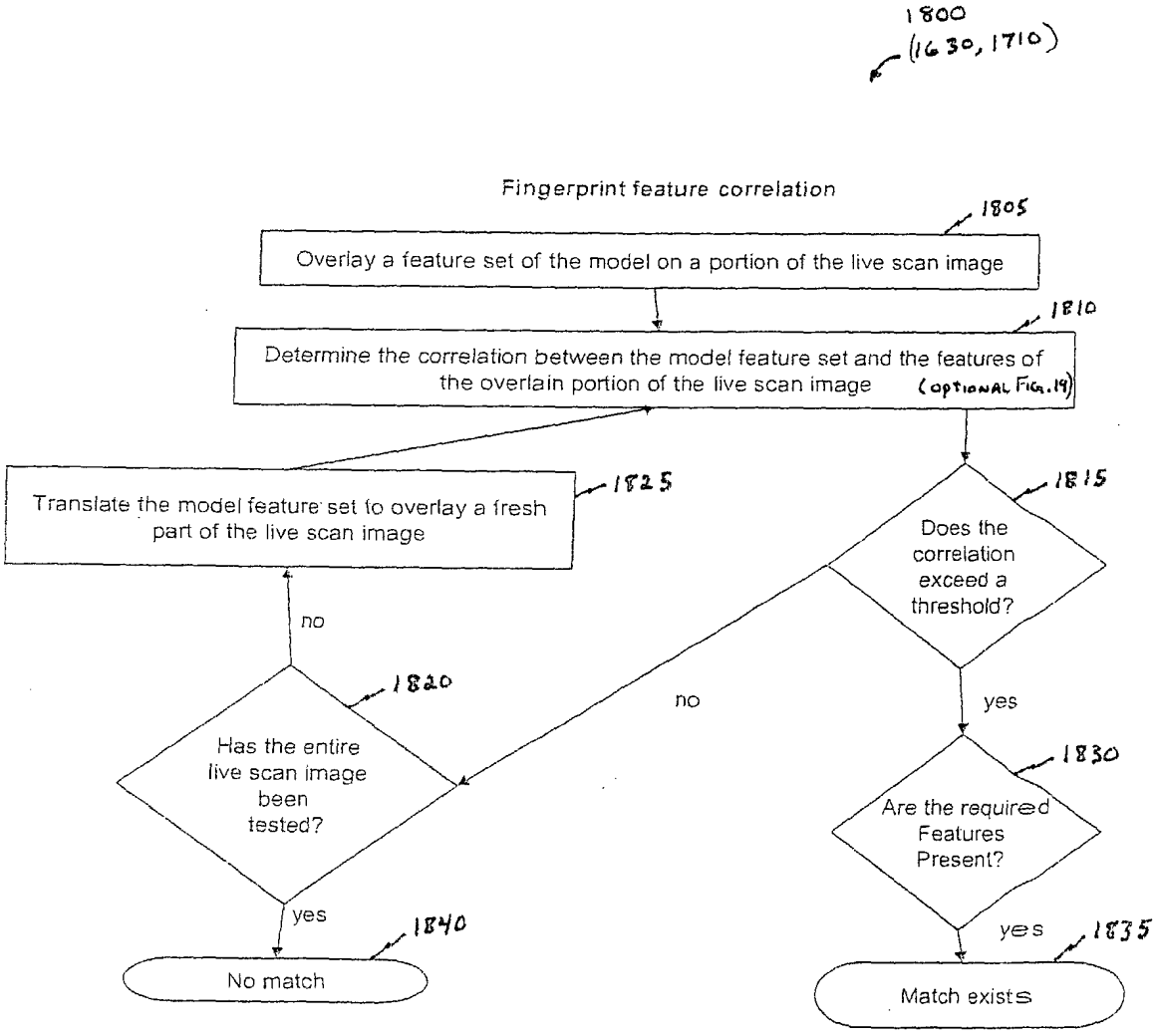
1800
(1630, 1710)
Fingerprint feature correlation
1805
Overlay a feature set of the model on a portion of the live scan image
1810
Determine the correlation between the model feature set and the features of the overlain portion of the live scan image (optional Fig. 19)
1825
Translate the model feature set to overlay a fresh part of the live scan image
1815
Does the correlation exceed a threshold?
no
yes
1820
Has the entire live scan image been tested?
no
yes
1830
Are the required Features Present?
yes
1840
No match
1835
Match exists

FIG. 18

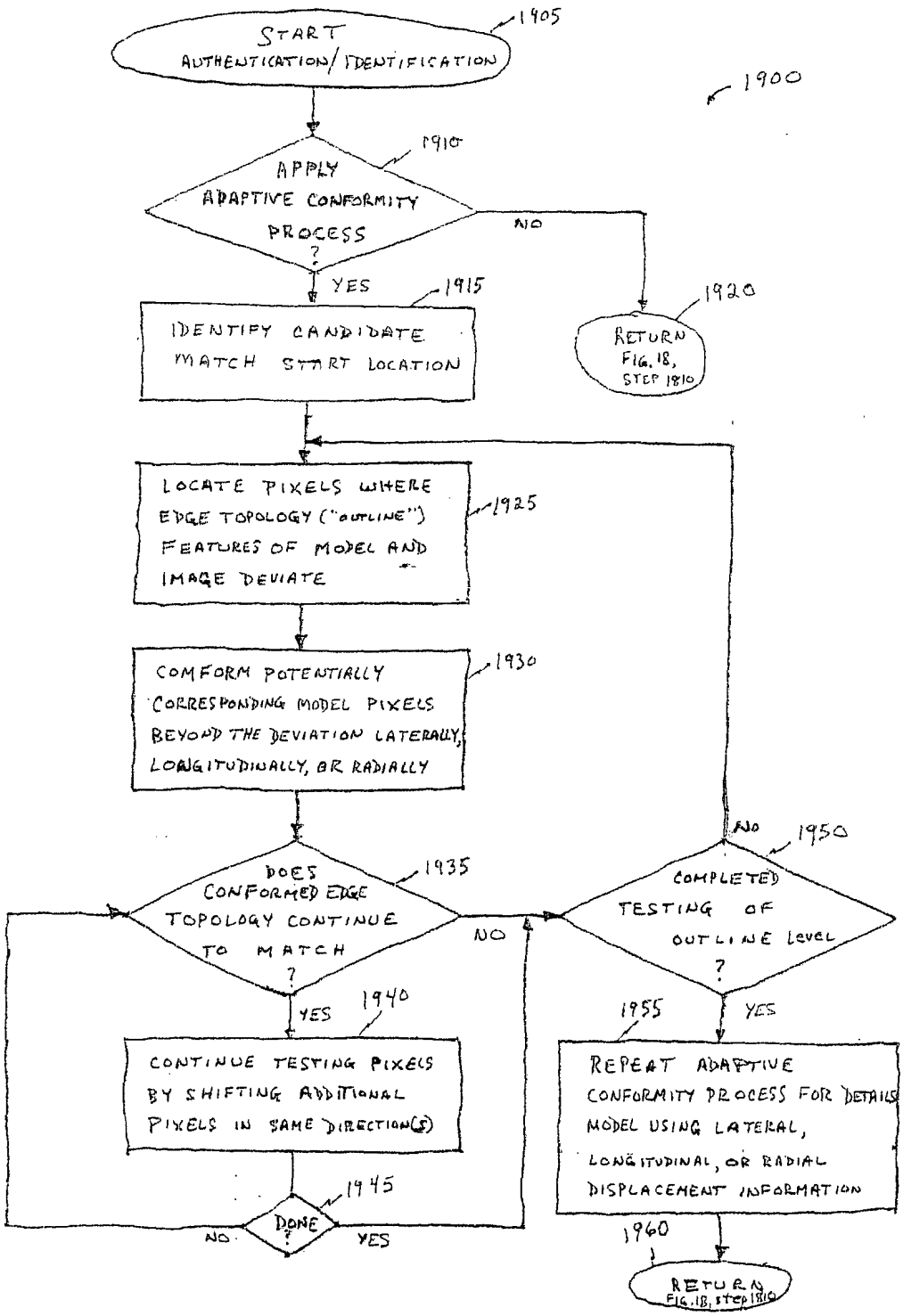
START AUTHENTICATION/IDENTIFICATION
1905
1900
APPLY ADAPTIVE CONFORMITY PROCESS ?
1910
NO
YES
1915
IDENTIFY CANDIDATE MATCH START LOCATION
1920
RETURN FIG. 18, STEP 1810
LOCATE PIXELS WHERE EDGE TOPOLOGY ("OUTLINE") FEATURES OF MODEL AND IMAGE DEVIATE
1925
CONFORM POTENTIALLY CORRESPONDING MODEL PIXELS BEYOND THE DEVIATION LATERALLY, LONGITUDINALLY, OR RADIALLY
1930
DOES CONFORMED EDGE TOPOLOGY CONTINUE TO MATCH ?
1935
NO
YES
1940
CONTINUE TESTING PIXELS BY SHIFTING ADDITIONAL PIXELS IN SAME DIRECTION(S)
DONE ?
1945
NO
YES
COMPLETED TESTING OF OUTLINE LEVEL ?
1950
NO
YES
1955
REPEAT ADAPTIVE CONFORMITY PROCESS FOR DETAILS MODEL USING LATERAL, LONGITUDINAL, OR RADIAL DISPLACEMENT INFORMATION
1960
RETURN FIG. 18, STEP 1810

FIG. 19

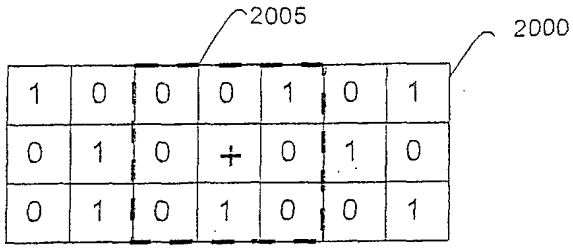

FIG. 20A

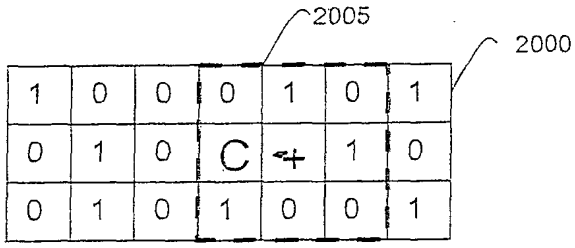

FIG. 20B